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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

AHEAD AND BACKING OPEN WATER CHARACTERISTICS OF MODEL PROPELLER 4716-NOZZLE SYSTEM

by

James G. Peck

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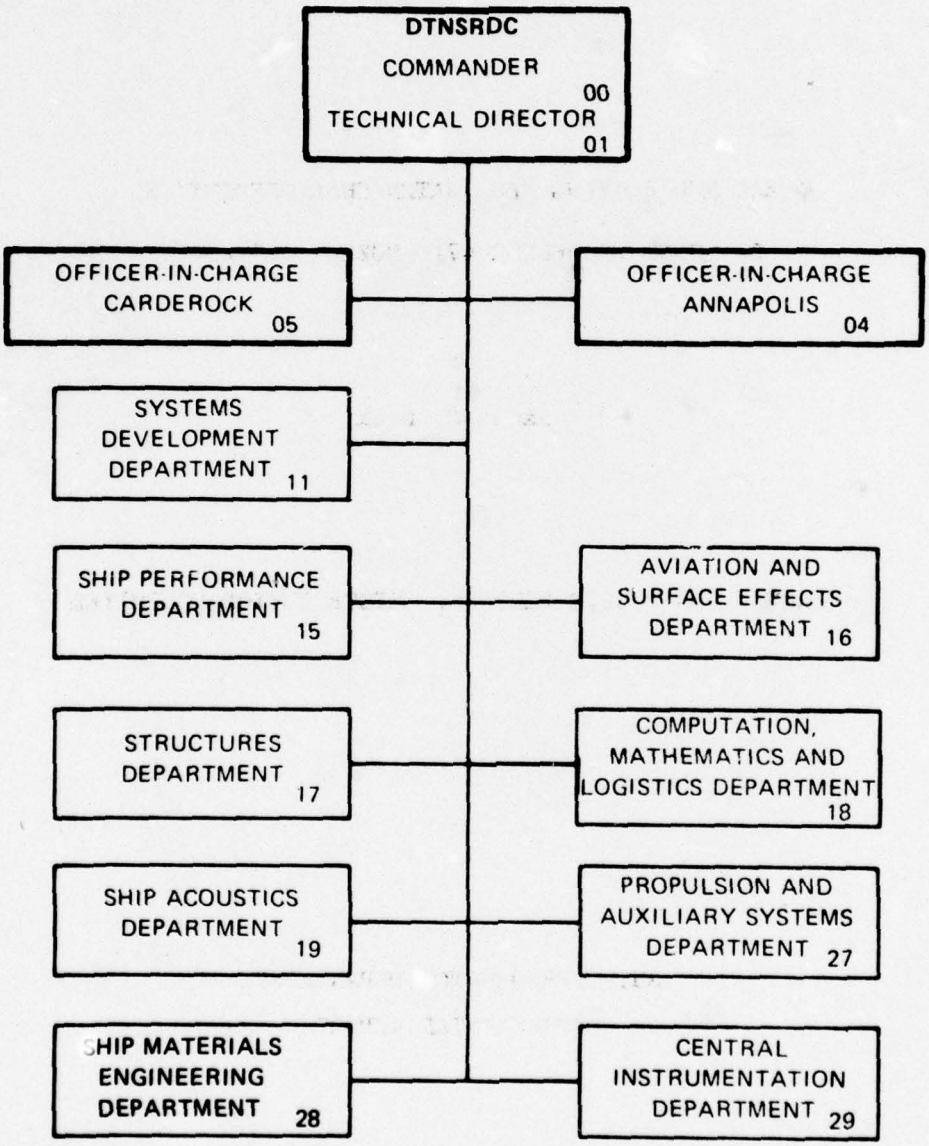

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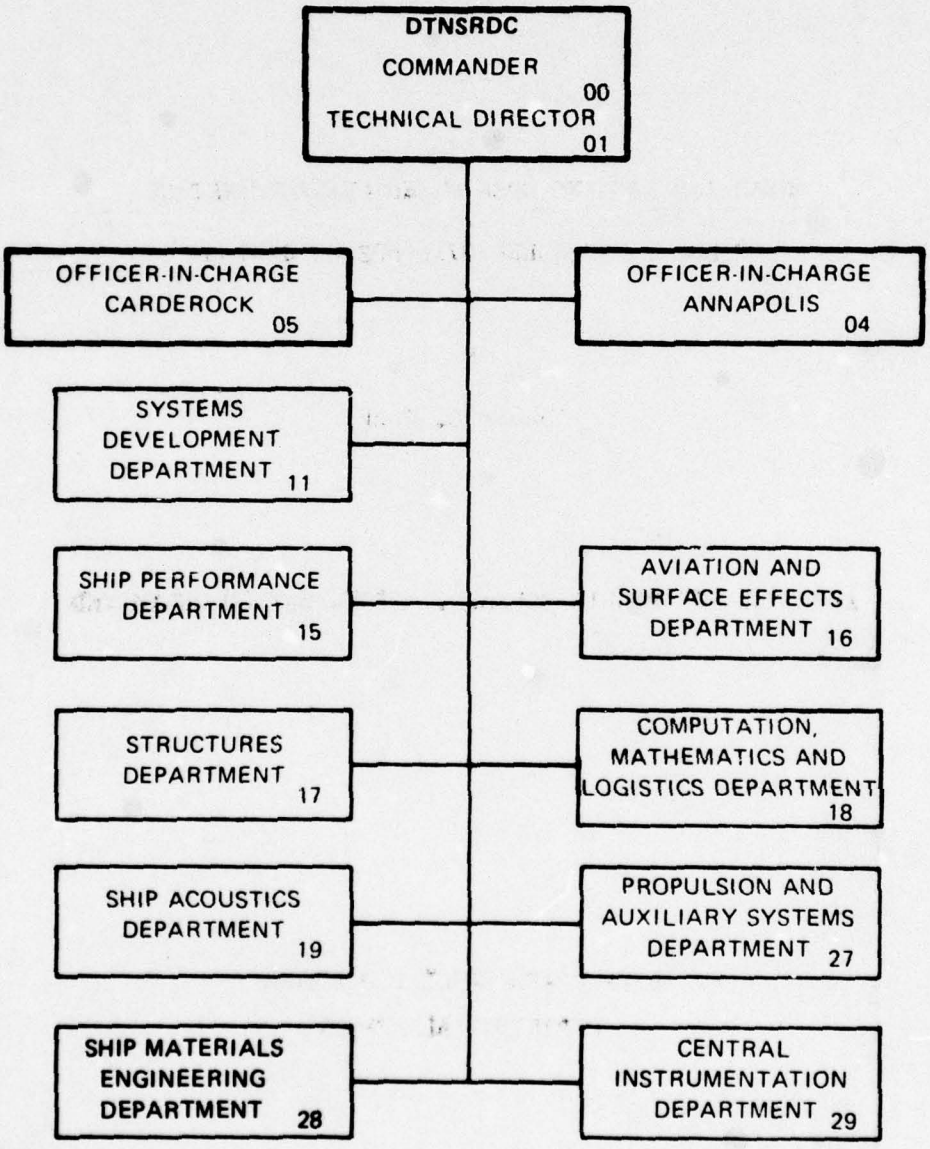

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Model Propeller 4716-nozzle system was characterized in open water, ahead and backing. Model propeller 4716 was also characterized, ahead and backing, without the nozzle. The propeller-nozzle system and propeller performance data are presented in this report. The results indicate that under heavily loaded conditions, especially in backing, the propeller- nozzle system is more efficient than the propeller alone at the same loading.

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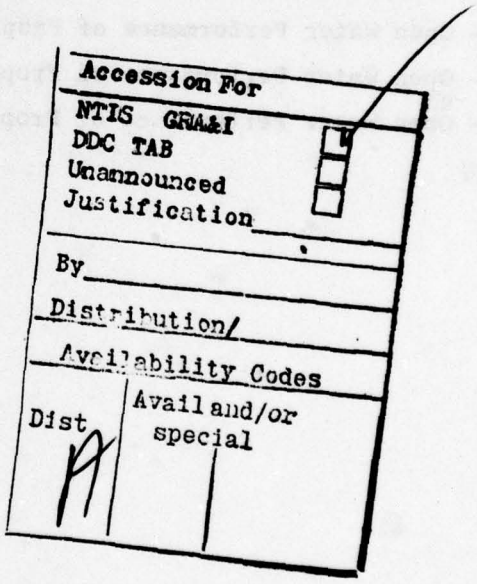

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NOTATION

		Dimensions
A_E	Expanded area of propellers blades $A_E = EAR\ (A_o)$	ft^2, m^2
A_o	Disc area of propeller $A_o = \frac{\pi D^2}{4}$	ft^2, m^2
A_p	Projected area of propeller blades $A_P = A_E\ (1.067-0.229\ P/D)$	ft^2, m^2
c	Blade section length	ft, m
$c_{0.7}$	Blade section at 0.7 radius	ft, m
D	Propeller diameter	ft, m
EAR	Expanded area ratio A_E/A_o	-
g	Acceleration due to gravity	ft/sec^2, m/sec^2
h	Propeller submergence	ft, m
J	Advance coefficient $J = V/nD$	-
K_T	Thrust coefficient $K_T = \frac{T_D + T_p}{\rho n^2 D^4}$	-
K_{TD}	Thrust coefficient $K_{TD} = \frac{T_D}{\rho n^2 D^4}$	-
K_T/J^2	Loading coefficient	-
K_Q	Torque coefficient $K_Q = \frac{Q}{\rho n^2 D^5}$	-
K_Q/J^3	Powering coefficient	
n	Propeller rotational speed	rev/sec, r/s
P	Propeller pitch	ft, m
P/D	Pitch-diameter ratio	-
P_A	Atmospheric pressure	lb/ft^2, N/m^2

		Dimensions
P_H	Static water pressure, $P_H = \rho gh$	lb/ft^2, N/m^2
P_V	Vapor pressure	lb/ft^2, N/m^2
Q	Propeller torque	lb/ft, N · m
Q_c	Torque load coefficient, $Q_c = \frac{2.55\ K_Q}{(J^2 + 4.84)(EAR)(1.067-0.229\ P/D)}$	-
R_n	Reynolds number at 0.7R $R_n = \frac{c_{0.7}\ V_{0.7}}{\nu}$	-
T_D	Nozzle thrust	lb, N
T_p	Propeller thrust	lb, N
V	Velocity of boat	ft/sec, m/sec
$V_{0.7}$	Resultant velocity of water at 0.7 radius of propeller $V_{0.7}^2 = \frac{J^2 + 4.83}{J^2}\ V^2$	ft/sec, m/sec
η	Propeller open water efficiency, $\eta = \frac{K_T}{K_Q}\ \frac{J}{2\pi}$	-
ν	Kinematic viscosity of water	ft^2/sec, m^2/sec
ρ	Mass density of water	$lb\text{-}sec^2/ft^4$, Kg/m^3
σ	Cavitation number, $\sigma = \frac{P_A + P_H - P_V}{1/2\ \rho v^2}$	-
α	Nozzle angle	degrees

		Dimensions
τ	Thrust load coefficient, $\tau = \frac{T_D + T_p}{1/2\rho A_p v_{0.7}^2}$	-

ABSTRACT

Model Propeller 4716-nozzle system was characterized in open water, ahead and backing. Model propeller 4716 was also characterized, ahead and backing, without the nozzle. The propeller-nozzle system and propeller performance data are presented in this report. The results indicate that under heavily loaded conditions, especially in backing, the propeller-nozzle system is more efficient than the propeller alone at the same loading.

ADMINISTRATIVE INFORMATION

This work was sponsored by the Naval Ship Engineering Center, Norfolk Division, Code 6661, under Program Element 60000N and Work Unit 1-1532-179.

INTRODUCTION

The Naval Ship Engineering Center Norfolk (NAVSEC NORDIV) requested that the David W. Taylor Naval Research and Development Center (DTNSRDC) determine the open water characteristics of a propeller-nozzle system designed by NAVSECNORDIV. A model of this design was manufactured by DTNSRDC. A drawing of the model propeller is shown in Figure 1 and a drawing of the nozzle is given in Figure 2. The cavitation performance of this system was determined at DTNSRDC.[1]

PROCEDURE

Open water characteristics of the propeller-nozzle system were obtained in the Center's deep water basin using the propeller boat. The experiments were conducted over a range of speed coefficients from zero velocity to zero propeller thrust, torque and RPM were measured. In addition, the axial force on the nozzle was measured. The force in the direction of positive propeller thrust is designated to be positive nozzle thrust. Upon completion of the ahead characterizations, the propeller-nozzle system was reversed and the characterizations were repeated in the backing mode. Propeller Reynolds numbers for the open water experiments

[1] Peck, James G. "The Effect of Propeller Pitch Distribution and Nozzle Angle on Propeller-Nozzle System Performance," DTNSRDC/SPD-0826-02 (Aug 1978).

ranged from 3.6×10^5 to 7.3×10^5.

PRESENTATION OF DATA AND DISCUSSION

The propeller and nozzle data were reduced to non-dimensional coefficients of K_T and K_Q. When the propeller was operated in the nozzle an additional coefficient K_{TD}, the coefficient of nozzle force, was calculated. K_T is the coefficient of total system thrust (propeller plus nozzle). Efficiency(η), loading coefficients (K_T/J^2 and τ), and powering coefficients (K_Q/J^3 and Q_c) were calculated from faired values of K_T and K_Q. Faired values of the force coefficients are given in Tables 1 to 4.

Curves of the system efficiency (see Figure 3) indicate that, in ahead operation under heavily loaded conditions, the propeller-nozzle system is somewhat more efficient than the propeller alone. Moreover, in backing operation (see Figure 4) under heavily loaded conditions the propeller-nozzle system is substantially more efficient than the propeller alone.

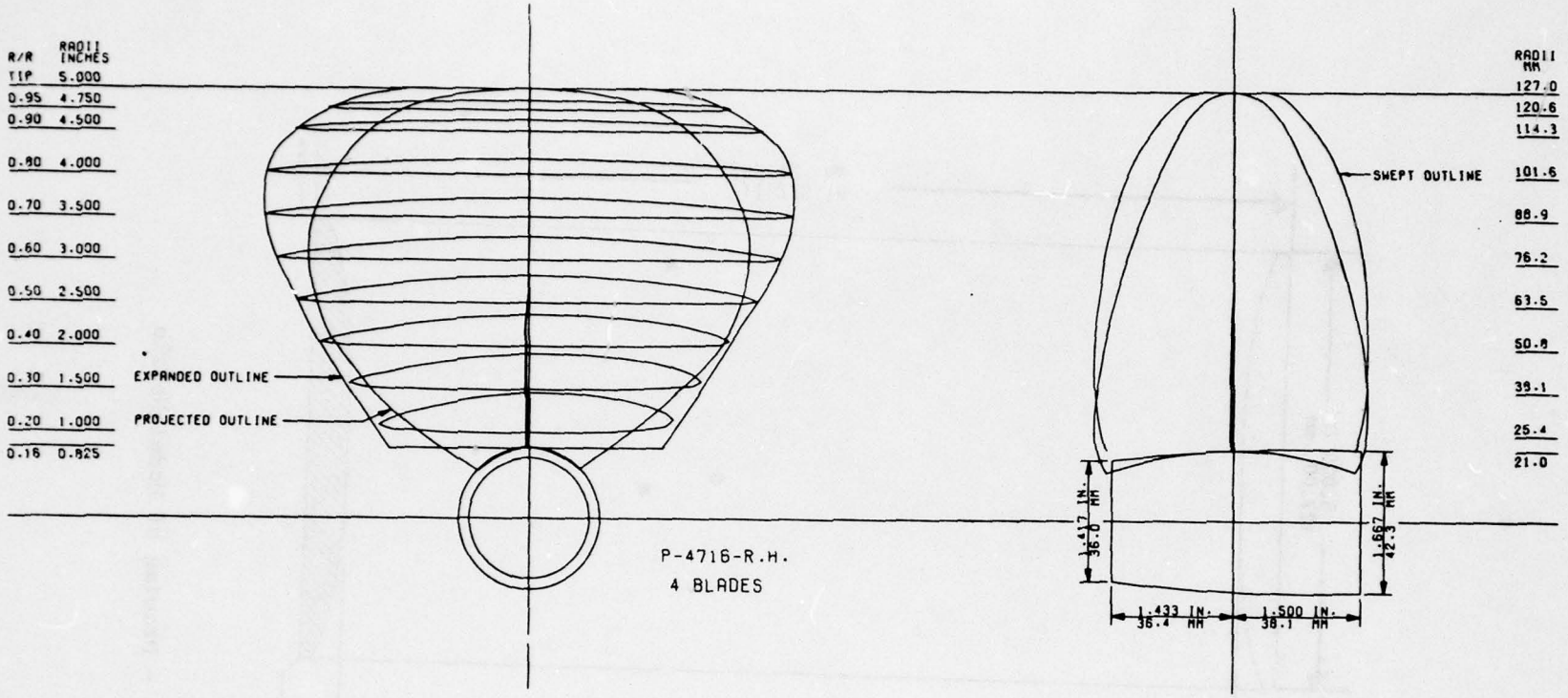

Figure 1 - Drawing of Model Propeller 4716

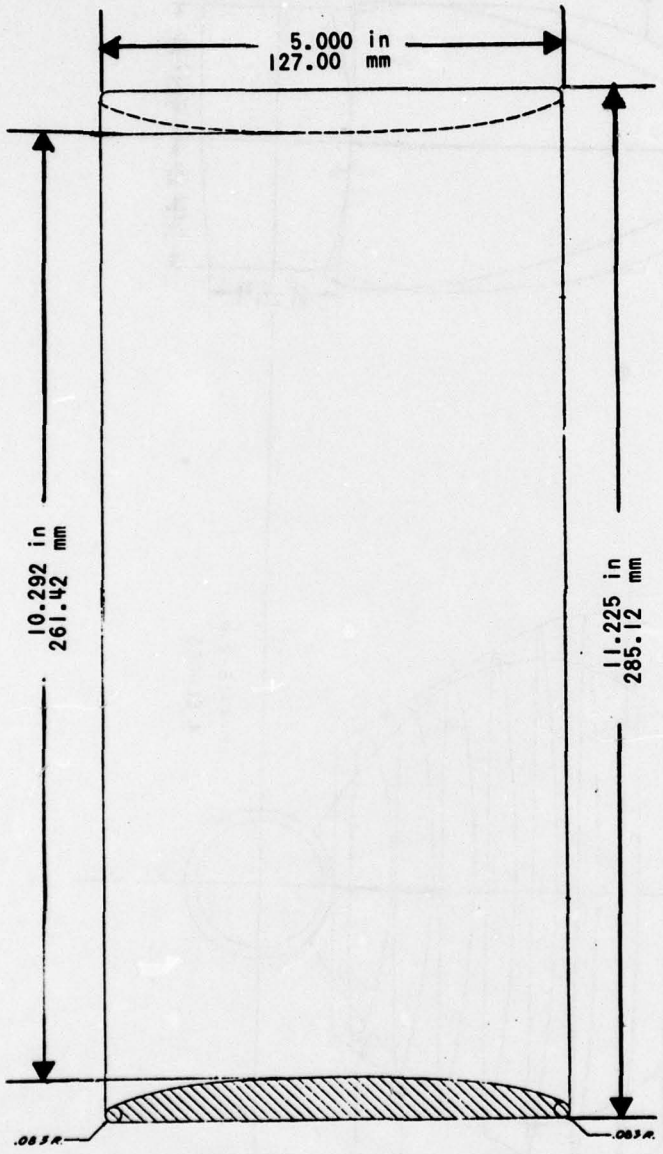

Figure 2 - Drawing of Model Nozzle

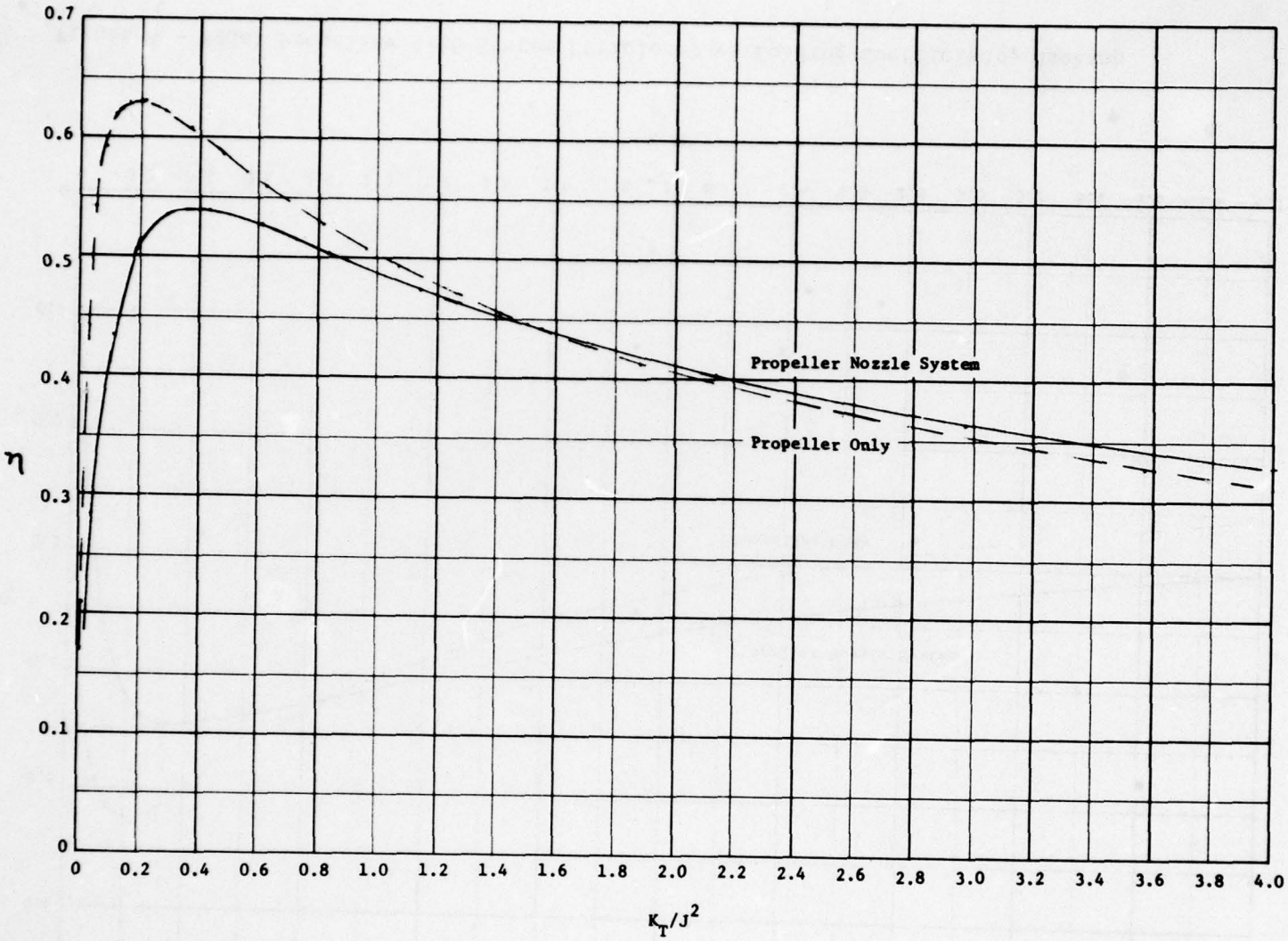

Figure 3 - Model Propeller 4716 System Efficiency vs Loading Coefficient, Ahead

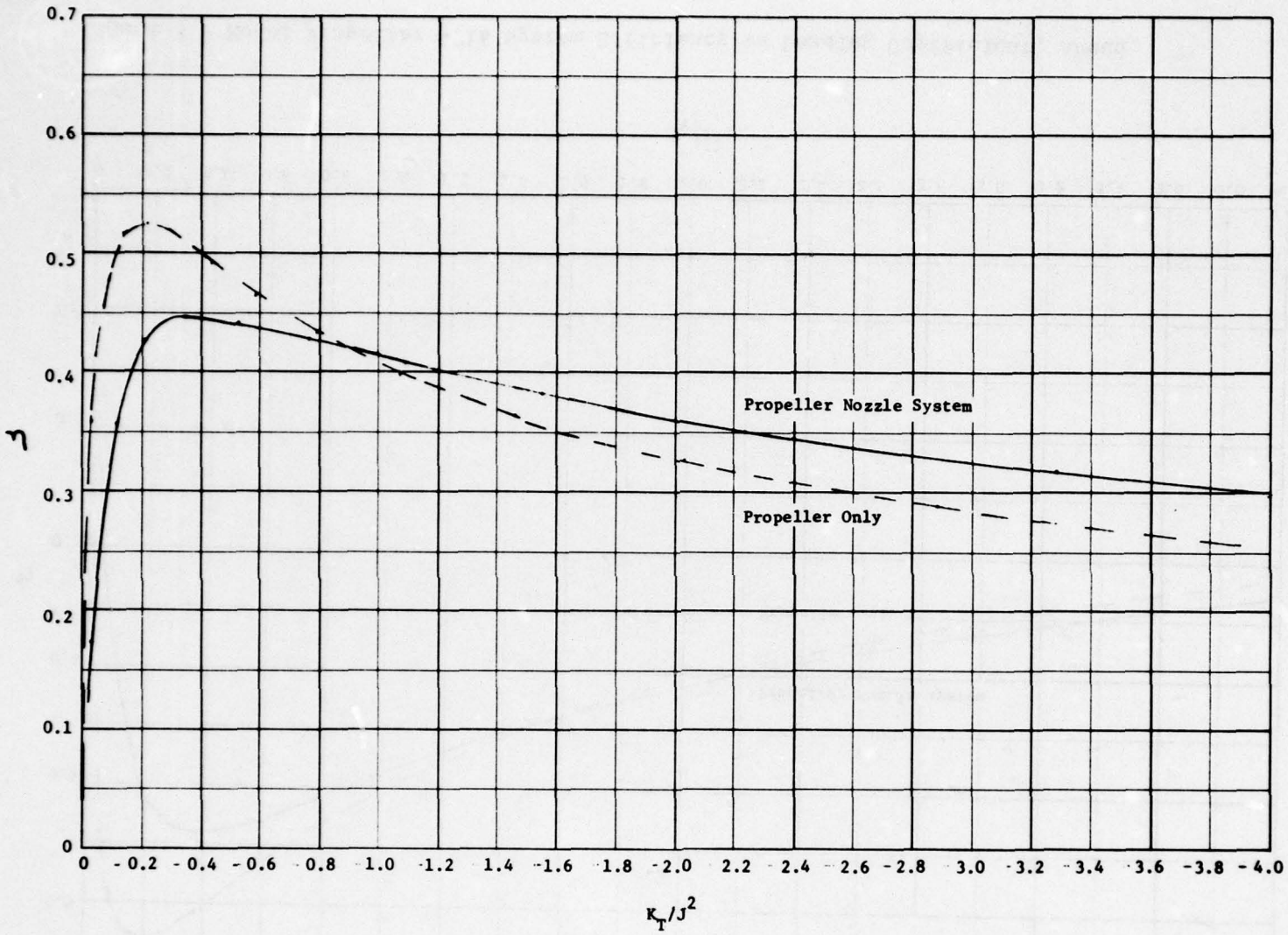

Figure 4 - Model Propeller 4716 System Efficiency vs Loading Coefficient, Backing

Table 1 - Open Water Performance of Propeller 4716 in Nozzle, Ahead

J	KTD	KT	10KQ	EFFIC	KT/J2	KQ/J3	QC	TAUC
.0500	.1516	.4789	.6331	.0602	******	******	.0375	.2833
.1000	.1379	.4582	.6201	.1176	******	******	.0367	.2706
.1500	.1239	.4398	.6103	.1720	******	******	.0360	.2591
.2000	.1099	.4222	.6013	.2235	******	7.5166	.0353	.2478
.2500	.0963	.4043	.5911	.2721	6.4686	3.7833	.0346	.2362
.3000	.0833	.3852	.5781	.3181	4.2799	2.1412	.0336	.2238
.3500	.0712	.3641	.5610	.3615	2.9724	1.3085	.0324	.2102
.4000	.0601	.3406	.5390	.4023	2.1286	.8421	.0309	.1951
.4500	.0501	.3142	.5114	.4400	1.5517	.5612	.0291	.1785
.5000	.0411	.2850	.4782	.4742	1.1399	.3826	.0269	.1604
.5500	.0332	.2529	.4397	.5035	.8359	.2643	.0245	.1408
.6000	.0262	.2183	.3962	.5260	.6063	.1834	.0219	.1202
.6500	.0199	.1816	.3490	.5384	.4296	.1271	.0190	.0988
.7000	.0141	.1436	.2991	.5349	.2931	.0872	.0161	.0772
.7500	.0083	.1052	.2485	.5054	.1871	.0589	.0132	.0558
.8000	.0023	.0675	.1991	.4318	.1055	.0389	.0104	.0353
.8500	-.0045	.0319	.1534	.2810	.0441	.0250	.0079	.0164
.9000	-.0125	-.0003	.1141	-.0034	-.0003	.0157	.0058	-.0001
.9500	-.0224	-.0271	.0846	-.4347	-.0300	.0099	.0042	-.0135

Table 2 - Open Water Performance of Propeller 4716, Ahead

J	KT	10KQ	EFFIC	KT/J2	KQ/J3	QC	TAUC
.0500	.5890	1.0019	.0468	******	******	.0593	.3484
.1000	.5637	.9591	.0935	******	******	.0567	.3329
.1500	.5392	.9171	.1404	******	******	.0541	.3176
.2000	.5147	.8752	.1872	******	******	.0514	.3021
.2500	.4898	.8331	.2339	7.8367	5.3321	.0487	.2862
.3000	.4641	.7907	.2803	5.1568	2.9285	.0460	.2696
.3500	.4375	.7478	.3259	3.5715	1.7442	.0432	.2525
.4000	.4100	.7046	.3704	2.5624	1.1009	.0404	.2349
.4500	.3816	.6611	.4134	1.8846	.7255	.0376	.2168
.5000	.3526	.6177	.4543	1.4105	.4942	.0348	.1984
.5500	.3232	.5745	.4925	1.0686	.3453	.0320	.1800
.6000	.2937	.5319	.5274	.8160	.2462	.0293	.1618
.6500	.2645	.4899	.5584	.6259	.1784	.0267	.1439
.7000	.2357	.4489	.5848	.4810	.1309	.0242	.1266
.7500	.2076	.4090	.6060	.3691	.0970	.0217	.1101
.8000	.1806	.3702	.6211	.2821	.0723	.0194	.0944
.8500	.1546	.3323	.6292	.2140	.0541	.0171	.0796
.9000	.1297	.2952	.6292	.1601	.0405	.0150	.0657
.9500	.1058	.2585	.6186	.1172	.0301	.0129	.0527
1.0000	.0825	.2215	.5930	.0825	.0221	.0109	.0405
1.0500	.0595	.1833	.5425	.0540	.0158	.0088	.0287
1.1000	.0361	.1430	.4417	.0298	.0107	.0068	.0171
1.1500	.0113	.0991	.2089	.0086	.0065	.0046	.0053
1.2000	-.0159	.0500	-.6085	-.0111	.0029	.0023	-.0073

Table 3 - Open Water Performance of Propeller 4716 in Nozzle, Backing

J	KTD	KT	10KQ	EFFIC	KT/J2	KQ/J3	QC	TAUC
.0500	-.1425	-.3874	-.4848	.0636	******	******	-.0287	-.2291
.1000	-.1342	-.3691	-.4659	.1261	******	******	-.0276	-.2180
.1500	-.1221	-.3517	-.4571	.1837	******	******	-.0270	-.2072
.2000	-.1077	-.3343	-.4535	.2346	-8.3568	-5.6683	-.0267	-.1962
.2500	-.0923	-.3158	-.4505	.2789	-5.0528	-2.6832	-.0264	-.1845
.3000	-.0771	-.2956	-.4448	.3174	-3.2849	-1.6474	-.0259	-.1718
.3500	-.0627	-.2733	-.4337	.3510	-2.2309	-1.0116	-.0251	-.1577
.4000	-.0497	-.2484	-.4155	.3806	-1.5527	-.6492	-.0238	-.1423
.4500	-.0384	-.2209	-.3892	.4066	-1.0911	-.4271	-.0221	-.1255
.5000	-.0290	-.1909	-.3548	.4281	-.7635	-.2838	-.0200	-.1074
.5500	-.0211	-.1585	-.3131	.4432	-.5240	-.1882	-.0175	-.0883
.6000	-.0144	-.1242	-.2656	.4466	-.3451	-.1230	-.0147	-.0684
.6500	-.0083	-.0887	-.2150	.4269	-.2099	-.0783	-.0117	-.0483
.7000	-.0017	-.0527	-.1644	.3573	-.1076	-.0479	-.0088	-.0283
.7500	+.0065	-.0173	-.1182	.1749	-.0308	-.0280	-.0063	-.0092
.8000	+.0178	+.0164	-.0813	-.2560	+.0255	-.0159	-.0043	+.0085
.8500	+.0337	+.0469	-.0597	******	+.0649	-.0097	-.0031	+.0241

Table 4 - Open Water Performance of Propeller 4716, Backing

J	KT	10KQ	EFFIC	KT/J2	KQ/J3	QC	TAUC
.0500	—.5043	—.9600	.0418	******	******	—.0569	—.2983
.1000	—.4840	—.9198	.0837	******	******	—.0544	—.2858
.1500	—.4606	—.8755	.1256	******	******	—.0516	—.2713
.2000	—.4350	—.8287	.1671	******	******	—.0487	—.2553
.2500	—.4082	—.7805	.2081	—6.5313	—4.9949	—.0457	—.2385
.3000	—.3806	—.7315	.2484	—4.2292	—2.7094	—.0426	—.2211
.3500	—.3527	—.6823	.2879	—2.8789	—1.5915	—.0394	—.2035
.4000	—.3245	—.6331	.3263	—2.0282	—.9892	—.0363	—.1859
.4500	—.2963	—.5837	.3635	—1.4630	—.6405	—.0332	—.1683
.5000	—.2679	—.5340	.3992	—1.0715	—.4272	—.0301	—.1507
.5500	—.2393	—.4839	.4329	—.7910	—.2908	—.0270	—.1333
.6000	—.2103	—.4330	.4639	—.5843	—.2005	—.0239	—.1159
.6500	—.1810	—.3814	.4910	—.4284	—.1389	—.0208	—.0985
.7000	—.1512	—.3289	.5122	—.3086	—.0959	—.0177	—.0813
.7500	—.1209	—.2757	.5236	—.2150	—.0654	—.0146	—.0641
.8000	—.0904	—.2224	.5174	—.1412	—.0434	—.0116	—.0472
.8500	—.0598	—.1697	.4767	—.0827	—.0276	—.0087	—.0308
.9000	—.0296	—.1186	.3577	—.0366	—.0163	—.0060	—.0150
.9500	—.0006	—.0709	.0123	—.0006	—.0083	—.0035	—.0003
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